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חוק הפטנטים, תשכ"ז-1967
Patent Law, 5727 - 1967

בקשה לפטנט
Application for Patent

לשימוש הלישכה
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אני, (שם המבקש, מענו ולגבי גוף מאוגד - מקום התאגדותו)
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(בעברית) (Hebrew)
שיטה ומכשיר למערכת עקיבה רב-תכליתית

(באנגלית) (English)
METHOD AND APPARATUS FOR MULTIPURPOSE MONITORING SYSTEM

hereby apply for a patent to be granted to me in respect thereof. מבקש בזאת כי ינתן לי עליה פטנט

*בקשת חלוקה - Application of Division	*בקשת פטנט מוסף - Application for Patent Addition	*דרישה דין קדימה Priority Claim		
*מבקשת פטנט from Application № ______ מס' dated ______ מיום	*לבקשה/לפטנט to Patent/Appl. № 150745 מס' dated 15/7/02 מיום	מספר/סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
*יפוי כח: ~~כללי~~ / ~~מיוחד - רצוף בזה / עוד יוגש~~ P.O.A.: ~~general / individual - attached / to be filed later~~ filed in case 150745 הוגש בענין				
המען למסירת מסמכים בישראל Address for Service in Israel לוצאטו את לוצאטו ת.ד. 5352 באר שבע 84152 מספרנו: 15212/02				
חתימת המבקש Signature of Applicant *Luzzatto & Luzzatto* By: Attorneys for Applicant		היום 5 בחודש ינואר שנה 2003 This of of the year		

לשימוש הלישכה

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15212/02

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METHOD AND APPARATUS FOR MULTIPURPOSE MONITORING SYSTEM

METHOD AND APPARATUS FOR MULTIPURPOSE MONITORING SYSTEM

This is an application for a patent of addition to pending application No. 150745.

Field of the Invention

This invention relates to a novel use of the system described in the co-pending application No. 150745 of the same applicant as a passive electro-optical radar system for locating foreign objects in the region of a monitored environment.

Background of the Invention

In a multiplicity of environments it is desirable to prevent, eliminate or reduce the existence and/or the intervention of foreign objects. Such types of environment can be airport runways, military bases, home industrial premises, etc. A foreign object can be a person, wildlife, birds, inanimate objects, vehicles, fire, etc.

Co-pending application No. 150745 discloses the entire content of a monitoring system that prevents, eliminates or reduces the existence and/or the intervention of such foreign objects. Fig. 1 schematically illustrates the monitoring system 10, according to a preferred embodiment

of the co-pending application No. 150745. System 10 comprises at least one Charged Coupled Device (CCD) camera 12, and/or at least one thermal camera 11 (i.e., Infra Red camera), motors 13 and a computerized system 15.

The computerized system 15 is responsible for performing the processing required for the operation of the monitoring system. The computerized system 15 receives data from the cameras, processes the received data in order to detect, in real-time, dangerous objects at the monitored area and then generates data regarding the detection of suspected dangerous objects.

Each camera that is attached to system 10 is rotated horizontally (i.e., pan) and/or vertically (i.e., tilt) by the motors 13. The rotation of the cameras is required for scanning the monitored area. Each camera attached to the system 10 is able to constantly scan a portion or the entire environment. The scanning is divided into several and a constant number of tracks, upon which each camera is focused.

In some cases a radar system is used in order to detect and locate the geographical location of targets or objects in the monitored area. However, it is extremely desirable to perform the detection without exposing the activity of the radar system.

Hence, it is therefore an object of this invention to provide a novel method, implemented by the apparatus of the co-pending Israeli Application No. 150745 for continuously and automatically detecting and finding the geographical location of dangerous objects that may constitute a menace to the monitored area, and this without generating a radiation.

It is another object of this invention to provide an enhanced display of the detected dangerous objects.

It is yet another object of this invention to reduce the number of false alarms.

Other objects and advantages of this invention will become apparent as the description proceeds.

While the embodiments of the invention are mainly described with reference to application in airfields, they, of course, also can be used for other applications in which there exists the threat of possible intrusion of persons, dangerous objects and/or vehicles into monitored areas, which usually are restricted. It is to be kept in mind that the possibility exists that dangerous objects may also not be natural, such as birds, but

artificial, used for sabotage or terror operations, or a fire endangering the monitored area.

The aircraft taking off or landing on the airfield, and vehicles or persons allowed to be in the monitored area will be designated hereinafter as "authorized bodies". All such birds, wildlife, persons, static objects, artificial objects, fire and any other FODs will generally be called "dangerous objects".

Summary of the Invention

The novel method of this invention comprises: a) generating a panoramic image and a map of the monitored area by scanning said area, said scanning being performed by rotating at least a pair of distinct and identical imagers around their central axis of symmetry; b) obtaining the referenced geographical location of a detected object by observing said object with said pair of imagers, said geographical location being represented by the altitude, range and azimuth parameters of said object; and c) displaying the altitude value of said object on said panoramic image and displaying the range and the azimuth of said object on said map.

Preferably, the imagers are cameras selected from the group consisting of: CCD or CMOS based cameras or Forward Looking Infra Red (FLIR) cameras.

The novel method of this invention implemented on apparatus which comprises: a) at least a pair of distinct and identical imagers for carrying out photographic observation of the controlled space or sections thereof; b) a set of motors for changing the sections of the said photographic observation; c) elaborator means for obtaining the referenced geographical location of a detected object in said controlled space, said geographical location being represented by the altitude, range and azimuth parameters of said object; d) means for generating a panoramic image and a map of the monitored area; e) means for displaying the altitude value of said object on said panoramic image and means for displaying the range and the azimuth of said object on said map.

Brief Description of the Drawings

In the drawings:

- Fig. 1 schematically illustrates a runway monitoring system, according to a preferred embodiment of the co-pending Israeli Application No. 150745;
- Fig. 2 schematically illustrates the solving of the general three dimensional position of an object in the Y direction;
- Fig. 3 schematically illustrates a combined panoramic view and map presentation of a monitored area;

- Fig. 4 schematically illustrates a scanning of a sector around a vertical rotation axis; and
- Fig. 5 schematically illustrates a scanning of a sector around a horizontal rotation axis.

Detailed Description of Preferred Embodiments

All the processing of this invention is digital processing. Grabbing an image by a camera, such as those of the apparatus of this invention, generates a sample image on the focal plane, which sampled image is preferably, but not limitatively, a two-dimensional array of pixels, wherein to each pixel is associated a value that represents the radiation intensity value of the corresponding point of the image. For example, the radiation intensity value of a pixel may be from 0 to 255 in gray scale, wherein 0 = black, 255 = white, and others value between 0 to 255 represent different levels of gray. The two-dimensional array of pixels, therefore, is represented by a matrix consisting of an array of radiation intensity values.

Hereinafter, when an image is mentioned, it should be understood that reference is made not to the image generated by a camera, but to the corresponding matrix of pixel radiation intensities.

Each sampled image is provided with a corresponding coordinates system, the origin of which is preferably located at the center of the sampled image.

In this invention, the determination of the background space, the objects evaluation programs, the extrapolation of the monitored paths of dangerous objects, the estimation of possible dangers of collision and the actions for eliminating such danger, is the same as that described in the co-pending Application No. 150745. Furthermore, the taken sequence of images of the monitored environment, as well as the detection of moving and/or static objects at the pixel processing stage, is also the same as that described in the co-pending Application No 150745.

According to a preferred embodiment of the present invention, each camera attached to the system 10 constantly scans a portion of the environment or its entirety. For a typical camera model (e.g., Raytheon commercial infrared series 2000B controller infrared thermal imaging video camera, of *Raytheon Company*, U.S.), which is suitable to be attached to system 10, it takes about 15 seconds to scan the complete runway environment that is covered by it. The scanning is divided into several and a constant number of tracks, upon which each camera is focused. The preferred scanning area is preformed at the area ground up to a height of, preferably but not limitatively, two hundred meters above the

area ground and also at a distance of a few kilometers, preferably 1 to 2 Km, towards the horizon.

Preferably but not limitatively, the cameras of system 10 are installed on a tower (e.g., flight control tower) or on other suitable pole or stand, at a height of between 25 to 60 meters above the desired monitored area ground.

The cameras can be positioned in a variety of ways. According to one preferred embodiment of this invention, a pair of identical cameras is located vertically one above the other on the same column, so that the distance between the cameras is approximately between 1 to 2 meters. The stand on which the cameras are located can be rotated by a motor, thus on each turn of the stand, both of the cameras are moved together horizontally. In such a configuration the cameras scan a sector, track or zone simultaneously. Preferably, but not limitatively, the distance between a pair of cameras is between 0.5 to 50 meter, horizontally, vertically or at any angle.

According to a preferred embodiment of this invention, system 10 (Fig. 1) is used as a system for detecting targets and their geographical location and this without generating radiation (i.e., a passive electro-optical radar).

Preferably, the geographical location of the targets is given in polar coordinates, e.g., range and azimuth.

In this invention, system 10 is used to measure and provide the geographical location (i.e., the location of the object in a three-dimensional coordinates system) of a detected object, such as the range, azimuth and altitude of the object. The geographical location is relative to a reference coordinates system on earth. The location of the object in the three-dimensional coordinates system is obtained due to an arrangement of at least two imagers, as will be described hereinafter. Preferably, the imagers are digital photographic devices such as CCD or CMOS based cameras or Forward Looking Infra Red (FLIR) cameras.

Preferably, at least a pair of identical CCD cameras, such as camera 12 of Fig. 1 and/or pair of FLIR cameras, such as camera 11 of Fig. 1 are positioned in such a way that system 10 sees each object, as it is captured by the charged coupled device of each camera, in two distinct projections. Each projection represents an image that comprises a segment of pixels wherein the center of gravity of a specific object in the image has specific coordinates, which differ from its coordinates in the other projection. The two centers of gravity of the same object have the pixel coordinate system $(x1, y1)$ for the first camera and the pixel coordinate system $(x2, y2)$ for the

second camera (e.g., each coordinate system can be expressed in units of meters).

System 10 essentially comprises at least two cameras preferably having parallel optical axes and having synchronous image grabbing. A rotational motion means such as motor 13 and image processing means, as described in the co-pending Application No. 150745. The image processing means is used to filter noise-originated signals and extract possible targets in the images and determine their azimuth, range and altitude according to their location in the images and the location disparity (parallax) in the two images coming from the two cameras (e.g., two units of CCD camera 12).

Obtaining the general location of an object in an image is identical for both directions X and Y of the coordinates system. Fig. 2 schematically illustrates the solving of the general three-dimensional position of an object in the Y direction.

Thus, solving the coordinate for the three-dimensional coordinates system is obtained as follows:

At first, the two following equations are provided,

$$\frac{y_2}{f} = \frac{Y_l - D}{Z_l} \qquad (1)$$

$$\frac{y_1}{f} = \frac{Y_l}{Z_l} \tag{2}$$

solving for *Z1* and *Y1*, we get:

$$Z_l = \frac{D * f}{\Delta y} \qquad \Delta y \equiv y1 - y2 \tag{3}$$

$$Y_l = \frac{y_1}{f} * Z_l = \frac{y_1 * D}{\Delta y} \tag{4}$$

and the same for *X1*:

$$X_l = \frac{x_1}{f} * Z_l = \frac{x_1 * D}{\Delta y} \tag{5}$$

wherein,

D - distance between the cameras optical axes;

f - focal length of the camera lenses;

(*x1, y1*) - coordinates of the target projection onto the first camera detector array;

(*x2, y2*) - coordinates of the target projection onto the second camera detector array;

(Xl,Yl,Zl) - coordinates of the target in the local coordinate system; and

(X,Y,Z) - coordinates of the target in the general world coordinate system

Due to the fact that the system 10 is scanning with the two cameras a certain sector, each scan step has a certain azimuth angle α which is dissimilarity with the system initial position. The system initial position represents the general world coordinate system. The magnitude of the angle α is used for correcting the dissimilarity by rotating the local step coordinates system thus that it will match the general world coordinate system.

In other words, the coordinates of an object in the local coordinate system differ from the coordinates of that object in the general world coordinate system. Thus, the transformations from the local coordinate system to the general world coordinate are calculated as follows:

(6)
$$X = X_l * \cos\alpha - Z_l * \sin\alpha$$
$$Y = Yl$$
$$Z = X_l * \sin\alpha + Z_l * \cos\alpha$$

This covert detection and localization of dangerous objects embodiment provides a passive operation of system 10 by imaging optical radiation in the far infrared range that is emitted by the relatively hot targets, such as

an airplane, helicopter, boat, a human being or any other object. This embodiment further provides a passive operation of system 10 by imaging optical radiation in the near infrared or vision ranges that is reflected by said targets.

In this embodiment, system 10 generates, by elaborator means, a panoramic image of the scene (i.e., of the monitored area) by rotating the pair of cameras around their central axis of symmetry, as well as a map of the detected targets in the scene that is regularly refreshed by the scanning mechanism of system 10. The combination of a panoramic image aligned with a map of the detected targets (i.e., dangerous objects) form a three-dimensional map of the targets, as shown in Fig. 3. Preferably, the elaborator means consisting of the computerized system 15 and a dedicated algorithm installed it, as will known to a person skilled in the art.

Reduction of the number of false alarm is also achieved by the reduction of clutter from the radar three-dimensional map. This is done, as has already been described in co-pending application No. 150745, by letting system 10 assimilate the surrounding response, coming from trees, bushes, vehicles on roads and the like and reducing the system response in these areas accordingly, all in an effort to reduce false alarms.

System 10 scans the monitored area by a vertical and/or horizontal rotational scanning of the monitored area. The vertical rotational scanning is achieved by placing the system axis of rotation perpendicular to the earth and the scanning is done over the azimuth range, which is the same as that done in typical radar scanning. The horizontal rotational scanning is achieved by placing the system axis of rotation horizontal to the earth and the scanning is done over elevation angles. These two last distinctions are needed in different situations in which the target exhibits certain activities that call for such scanning. Of course, by adding more than two imager means (e.g., such as three or four CCD cameras), the accuracy of the range measurement is increased.

Fig. 3 schematically illustrates a combined panoramic view and map presentation of a monitored area. In Fig. 3, the electro-optical radar (i.e., system 10) is scanning with a viewing angle confined by the two rays, 20 and 30. The radar display is arranged in a graphical map presentation, 40, and a panoramic image 50. In the map, the relative locations of the targets, 60 and 70, can be seen, while in the panoramic image, 50, the heights of the targets can be seen. The displayed map and panoramic image are both refreshed with the radar system rotational scanning. The combination of a panoramic view, providing altitude and azimuth, with a map, providing azimuth and range, gives a three-dimensional map of targets. Preferably, the geographical position of each detected object being

displayed by using any suitable three-dimensional software graphics, such as Open Graphic Library (OpenGL), as known to a skilled person in the art.

Using two FLIR cameras positioned on the system vertical axis and two additional video cameras (e.g., CCD cameras), operating in the normal vision band, located horizontally from the two sides of the system vertical axis, the different camera types are optimal on different conditions: the FLIRS are optimal at night and in bad weather and the video cameras are optimal in the daytime and in good weather.

In Fig. 4, the pair of cameras 12 of the electro-optical radar embodiment of system 10 is rotating around the vertical rotation axis 80 and providing an image of scene, which is confined between the rays 100, 110, 120 and 130. The provided image of the scene is analogous to a radar beam, thus while the cameras are rotating around axis 80, the beam is scanning through the entire sector 135.

In Fig. 5, another scanning option is introduced in which the cameras 12 of the electro-optical radar (i.e., system 10) are rotating around the horizontal rotation axis 140, thereby scanning sector 160. Preferably, the scanning of this sector 160 is performed by the same method as the vertical scanning.

According to this embodiment of the present invention, the distance of the targets is measured by using radiation emitted or reflected from the target. The location of the target is determined by using triangulation with the two cameras. This arrangement does not use active radiation emission from the radar itself and thus remains concealed while in measurement. The distance measurement accuracy is directly proportional to the pixel object size (the size of the pixel in the object or target plane) and to the target distance and inversely proportional to the distance between the two cameras. The pixel size and the distance between the cameras are two system design parameters. As the distance between the two cameras increases and the pixel size decreases, the distance measurement error decreases.

Another feature of this embodiment is the ability to double-check each target detected, hence achieving a reduction in the number of false alarms. The passive operation allows a reliable detection of such targets with a relatively low false alarm rate and high probability of detection by utilizing both CCD and/or FLIR cameras to facilitate double-checking of each target detected by each camera. Each camera provides an image of the same area but from a different view or angle, thus each detected target at each image from each camera should be in both images. As the system geometry is prior knowledge, hence the geometrical transformation of one

image to the other image is known, thus each detected pixel in one image receives a vicinity of pixels in the other image, and each of them may be its disparity pixel. Thus only a pair of such pixels constitutes a valid detection.

From the above description of the system scanning methods, the system display of detected targets may include all the measured features, e.g., target size, distance from the system, azimuth, and altitude. The present invention uses a panoramic image of the scene together with its map of detected targets to present the above features, in a convenient and concise manner.

The above examples and description have of course been provided only for the purpose of illustration, and are not intended to limit the invention in any way. As will be appreciated by the skilled person, the invention can be carried out in a great variety of ways, employing more than one technique from those described above, all without exceeding the scope of the invention.

CLAIMS

1. Method for the monitoring of an environment, comprising:

a) generating a panoramic image and a map of the monitored area by scanning said area, said scanning being performed by rotating at least a pair of distinct and identical imagers around their central axis of symmetry;

b) obtaining the referenced geographical location of a detected object by observing said object with said imagers, said geographical location being represented by the altitude, range and azimuth parameters of said object; and

c) displaying the altitude value of said object on said panoramic image and displaying the range and the azimuth of said object on said map.

2. Method according to claim 1, wherein the imagers are photographic devices selected from the group consisting of: CCD or CMOS based cameras or Forward Looking Infra Red (FLIR) cameras.

3. Apparatus according to claim 1, in which the distance, in an angle, between each two imagers is between 0.5 to 50 meters.

4. Apparatus for the monitoring of an environment, which comprises:

a) at least a pair of distinct and identical imagers for carrying out photographic observation of the controlled space or sections thereof;

b) a set of motors for changing the sections of the said photographic observation;

c) elaborator means for obtaining the referenced geographical location of a detected object in said controlled space, said geographical location being represented by the altitude, range and azimuth parameters of said object;

d) means for generating a panoramic image and a map of the monitored area;

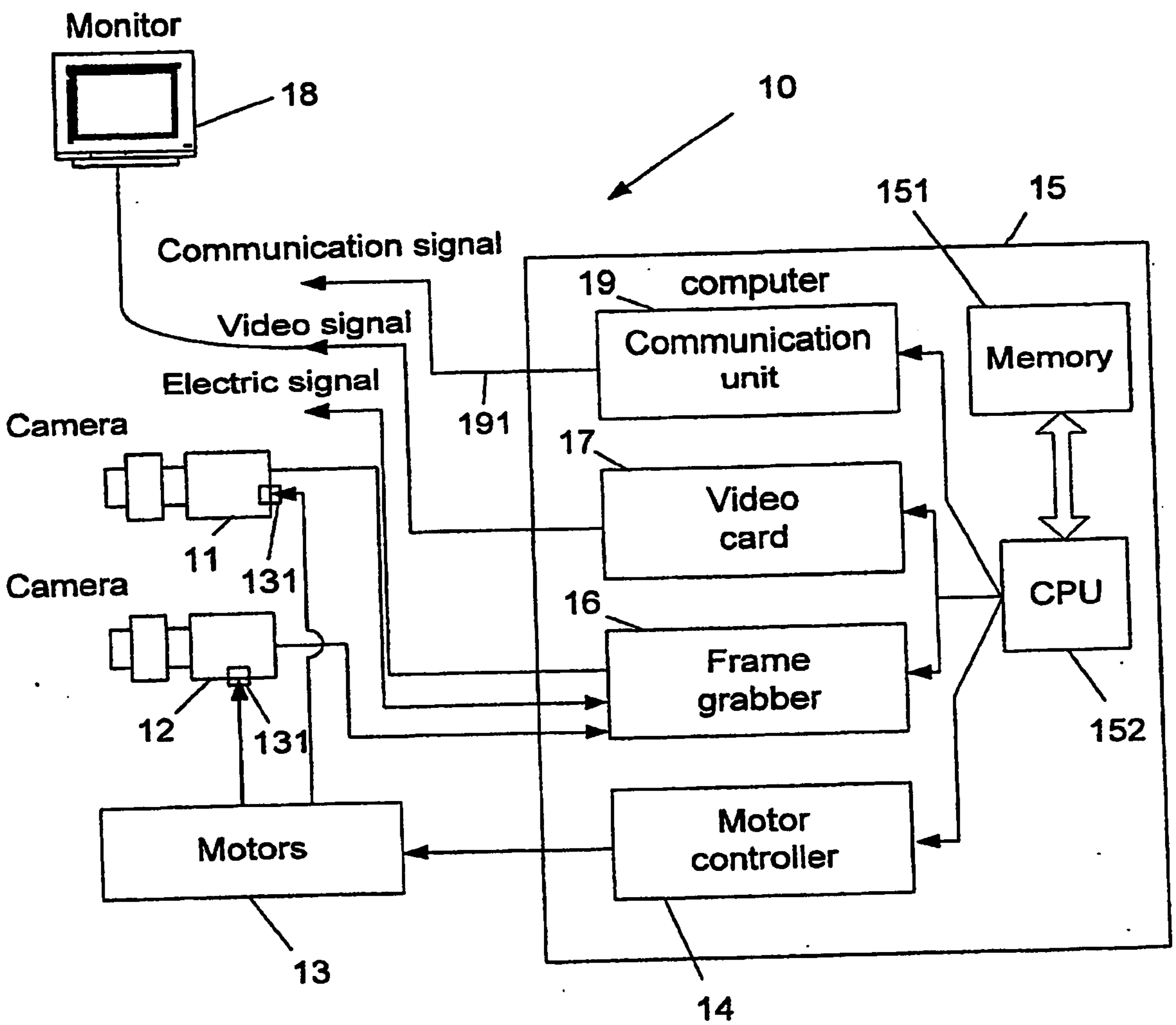
e) means for displaying the altitude value of said object on said panoramic image and means for displaying the range and the azimuth of said object on said map.

5. Apparatus according to claim 4, in which the imagers are photographic devices selected from the group consisting of: CCD or CMOS based cameras or Forward Looking Infra Red (FLIR) cameras.

6. Apparatus according to claim 4, in which the distance, in an angle, between each two imagers is from 0.5 to 50 meters.

7. Apparatus according to claim 4, in which the means for displaying the monitored area are using three-dimensional software graphics where the geographical location of each detected object is indicated as a three-dimensional image.

לוצאטו את לוצאטו
LUZZATTO & LUZZATTO
By עו"ד


Monitor
18
10
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Communication signal
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computer
Video signal
Communication unit
Memory
Electric signal
191
Camera
17
Video card
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131
CPU
Camera
16
Frame grabber
12
131
152
Motors
Motor controller
13
14

Fig. 1

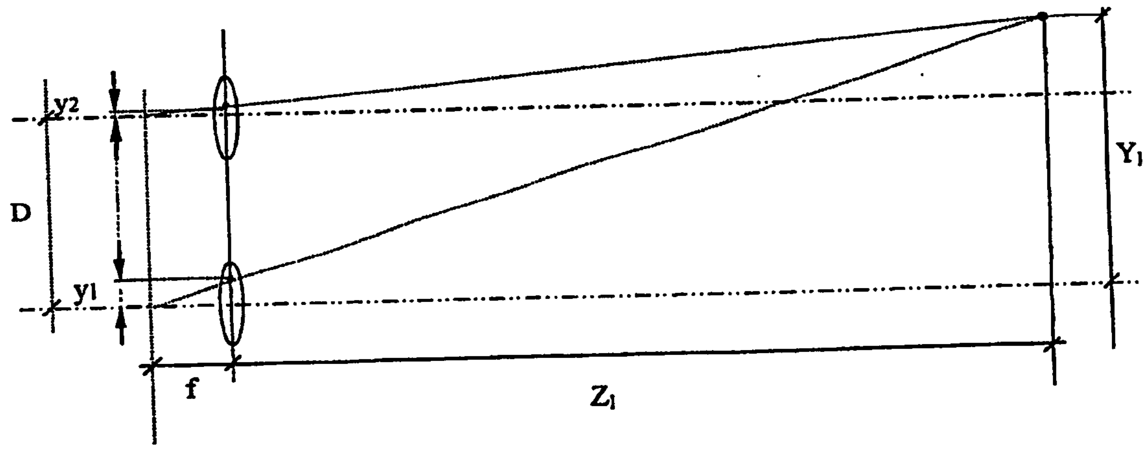

Fig. 2

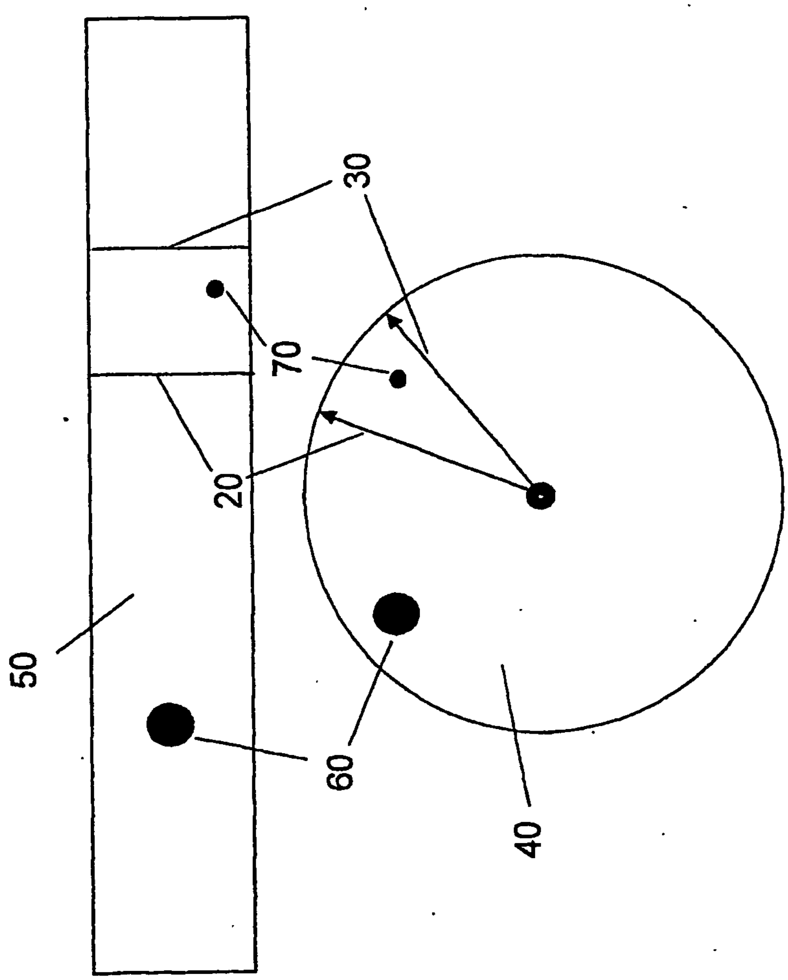

Fig. 3

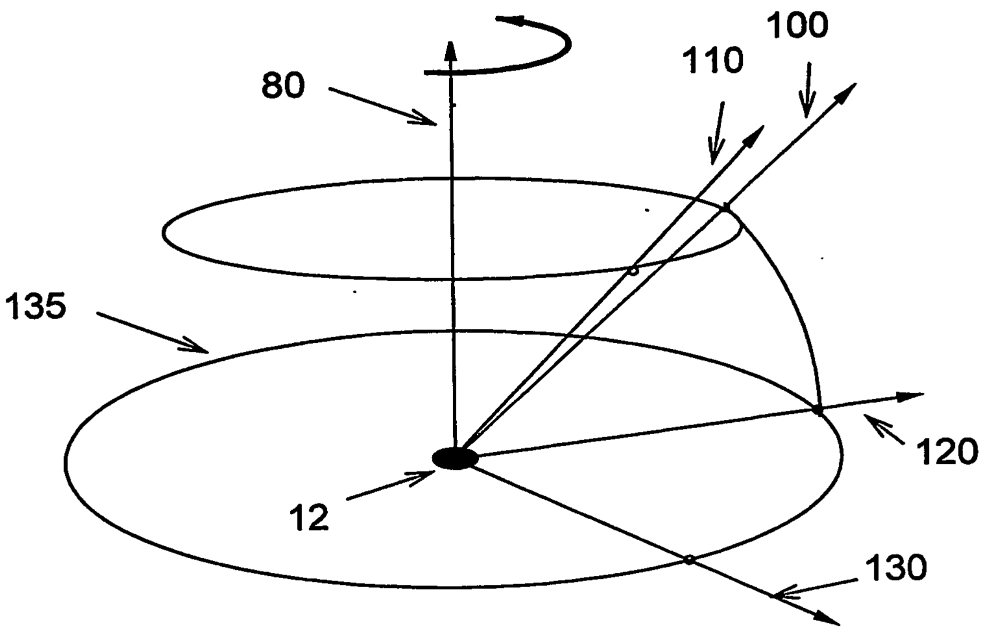

Fig. 4

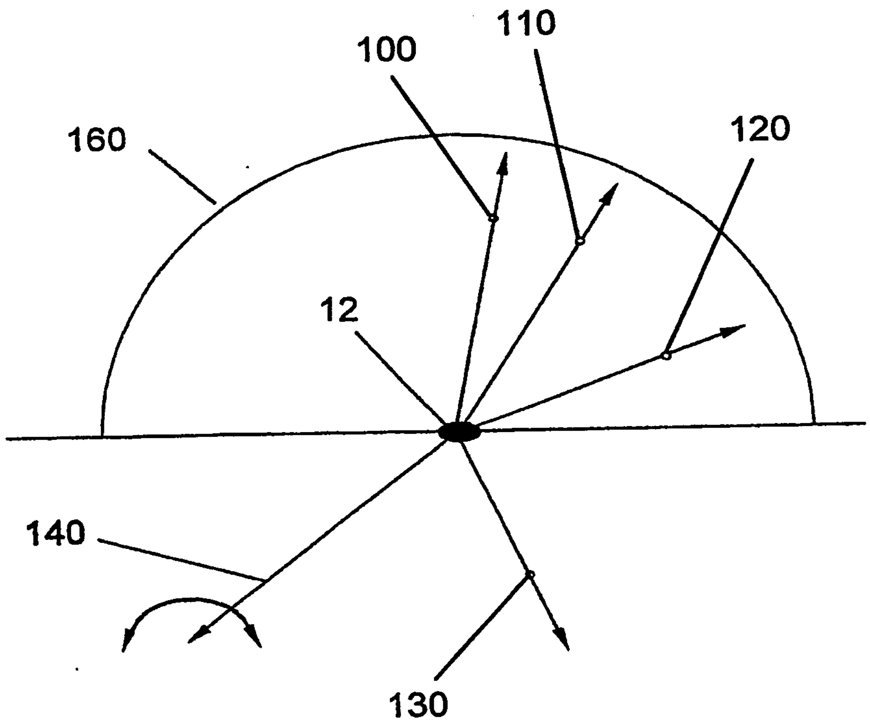

Fig. 5